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PRACTICAL PHYSICS

WE propose in the present article to carry out the intention expressed in a former number (vol. xii. p. 206) of giving fuller details of the practical instruction in physics, which forms a part of the summer course of instruction given to science teachers by the Science and Art Department. The teaching of practical physics presents several difficulties, which have no doubt largely militated against its general introduction into the course of scientific education. It has not yet been systematised. Unlike practical chemistry one cannot select a practical text-book on physics and give it to the students; for such text-books do not yet exist in English. We are not forgetting the translation of Weinhold's *Experimental Physics*, which we lately reviewed in these columns; but that book is unsuitable for most students owing to its unwieldy size and high price.

Even if works on practical physics were at hand, another difficulty is encountered in the costly nature of the apparatus involved in studying physics. This no doubt is one of the main difficulties that the teacher has to overcome, and in this respect physics differs widely from chemistry, for it is out of the question to provide a complete set of physical apparatus for every two or three students. To meet this difficulty one may distribute different instruments among the students and allow them in turn thoroughly to master what is put before them. This plan might do for a small class, the members of which could use their fingers already. But it is at best an unsatisfactory method, for it leaves the student completely at sea directly he begins to communicate the instruction he has received, unless he can purchase what he has been in the habit of using, and this is not often within his means to do. Another course is first to teach the students how to make simple apparatus for themselves, and then to show them how to use it. The advantages of this plan are apparent. Students unaccustomed to manipulation find to their astonishment, when they begin, that all their fingers have turned into thumbs, and are amazed at their clumsiness and stupidity. Very soon, however, fingers begin to reappear, and the first successful piece of apparatus that is made gives them a confidence in themselves which they had thought impossible to attain. The pleasure of having made an instrument is increased a hundred-fold when it is found that by their own handiwork they may verify some of the more important laws in physics; or make physical determinations, which before they would have considered it presumption to attempt, even with ready purchased apparatus. In order to carry out this plan successfully, minutely detailed instructions must be given to each student concerning the construction of the apparatus he has to make, and it is moreover obvious that the instruments should not take too long to make, and that the first trials should be with the simplest apparatus possible.

Let us now look at the science teachers at work at South Kensington. Each one has given to him a page of printed instructions for the day's work. These instruc-

tions have grown up within the last few years under the direction of those who have been associated with Dr. Guthrie in this undertaking, namely, Professors G. C. Foster and W. F. Barrett, together with the valuable aid of Mr. W. J. Wilson.

In the teaching of Practical Physics perhaps no subject lends itself more readily to practical work than Electricity and Magnetism; and as nearly every science student has had some little practice in this direction, this branch of physics commends itself as best fitted to begin with.

The first day's work on Electricity and Magnetism commences with the construction of simple electrical apparatus, as for example "Make a glass tube for electrical excitation;" then comes what to do in the way of cutting the tube and closing the ends. This introduces some to their first experience with the blow-pipe and the manipulation of glass, in which they rapidly gain courage and proficiency.

After this they are told to make a balanced glass tube as follows:—

"Glass tube about 12 inches \times $\frac{3}{4}$ inch. Clean and dry inside, close and round one end, nearly close other end. Balance on edge of triangular file, mark centre with file. Soften one side of tube at centre with Bunsen burner, push in side with point so as to make conical cap. Avoid having file scratch at apex of cap."

Rubbers, pith balls, proof-planes are made, and the fundamental laws of electricity are tried before the day is over. Next day a gold leaf electroscope has to be made, and some capital instruments of this kind are turned out. The insulation of these electroscopes is so high that we have seen them retain a charge for an hour or more when the body of the instrument was standing in water. The secret of the insulation consists in using clean flake shellac; a little of this substance is melted in the hole through which the wire stem of the instrument has to pass, the stem is then warmed and pushed through the shellac so as to leave about a quarter of an inch thickness of shellac all round the wire. Without attempting to follow each day's work, we notice in passing that the distribution of electricity is tried by using card-board cones and cylinders covered with gilt paper, a Leyden jar with movable coatings is constructed, an electrophorus is made and various experiments tried with it, and even a Thomson's quadrant electrometer is among the more ambitious pieces of apparatus that are attempted.

Omitting Magnetism, which is not so fully developed as the other subjects, we come to Current Electricity. One of the first things that has now to be made is an astatic galvanometer, which occupies the greater part of one day's work. This instrument works so well, that for the sake of other science students we quote the following instructions for making it:—

"Wind about 50 feet of fine covered copper wire on wood block; remove wood; secure coil by tying with thread; insulate and stiffen coil by soaking with melted paraffin or shellac varnish. Make another similar coil; fix the two coils side by side on round wood block, leaving about $\frac{1}{4}$ inch space between them and soldering two of the free ends of coils together so as to make one continuous coil. Solder other two ends of wire to binding screws fixed about $\frac{1}{2}$ inch from edge of block. Lead ends of the wire also into two little hollows cut in wood block by side of binding screws, so that these depressions may serve as mercury cups; they are convenient for shunting

the galvanometer. Bend stout brass wire into flat-topped arch and fix firmly in block; the straight portion of wire at top of arch having upon it a cork roller for raising or lowering needles. Magnetise two sewing needles and fix (with opposite poles adjoining) $\frac{1}{2}$ inch apart by means of twisted fine copper wire. On same axis, $\frac{1}{4}$ inch above upper needle, fix glass thread about 4 inches long to serve as pointer. Suspend needles by silk fibre and attach fibre to cork roller. Cut card into circle 4 inches diameter and graduate circumference into degrees. Place (but do not fix) card in proper position over coil, supporting it on two corks cemented to board. Make needles as far as possible astatic. Place them in position and cover all with glass shade."

After some preliminary work with the galvanometer, a Daniell's cell and a simple form of Wheatstone's bridge are made; then a rheochord and a set of resistance coils. Then comes the following work with these instruments, in each case the necessary instructions being printed under the work to be done:—

"1. Measure relative resistances of different lengths of the same copper wire by Wheatstone's Bridge. 2. Find lengths of copper wires by measuring their relative resistances, the length of one of the wires being known. 3. Ascertain relation between resistance and weight. 4. Ascertain effect of temperature on resistance. 5. Experimentally establish the laws of divided circuits. 6. Measure the external resistance of your cell. 7. Compare the electromotive force of your cell with that of a Grove's cell."

In this direction there is, of course, an almost unlimited field for practical work, but other parts of the subject claim attention, and the time that can be given to the whole is extremely limited. Our space will not allow us to detail further what is done in electricity, nor can we give more than a hasty glance to the other subjects that are taken up in successive years by the science teachers.

Sound is not a very promising branch of Physics for practical work; nevertheless, nine or ten days are usefully spent on this subject. A monochord is the *pièce de résistance* here, and when this is made the laws of the transverse vibration of strings are verified, and the following problems solved by its means:—"1. Weigh pieces of metal of unknown weight. 2. The pitch of one tuning fork being known, ascertain that of another unknown. 3. The diameter of a German silver wire being known, ascertain its specific gravity." By means of the ordinary shilling tuning forks some useful experiments are made, and finally the velocities of sound in various solid, liquid, and gaseous bodies are determined in different ways and with a satisfactory approximation to the truth. This will indicate merely the course of practical work in sound.

Heat and Light offer more facilities for practical work. In Heat, a differential air thermometer is first made, then an alcohol thermometer is determined and graduated; the maximum density of water is tried by simple hydrometers; a bulb tube is made, and here we quote two experiments in which this bulb is used for determining coefficients of expansion:—

"Determine mean Coefficients of absolute expansion of Water and Alcohol between temperature of the day and 50° C. above.

"Weigh bulb tube filled with liquid at temperatures t and T . Calling weight of liquid at t , W and loss of weight at T , w , the Coefficient of apparent expansion is

$\frac{w}{W - w}$. The real expansion is obtained by adding to this the Coefficient of expansion of the glass. (See next experiment.)

"Determine mean Coefficient of expansion of glass of thermometer tubing for 50° C. above the temperature of the day.


"Weigh bulb tube full of mercury at temperatures t and T , and so obtain Coefficient of apparent expansion of mercury ($= B$). Then assuming Coefficient of real expansion of mercury as .00018 ($= C$), $C - B =$ mean Coefficient of glass."

The determination of specific and latent heat follows this, and a few experiments on radiant heat conclude this part.

In Light a large range of subjects is available for practical work, but the necessary instruments are more numerous, and require rather more skill in their manufacture. Nevertheless several experiments will occur to every teacher which can be made with very little preparation, such, for example, as trying the law of inverse squares, comparing in various ways the illuminating powers of different sources of light, &c. Here is something rather more difficult:—

"Make an instrument for measuring vertical heights by reflection." Instructions for this are given, and the instrument is then used for measuring the heights of ceilings, doors, &c., after it has been fully explained.

Silvering solutions are prepared and employed for many purposes; little concave and convex mirrors, for example, are made out of large watch-glasses silvered by this process of deposition, and the foci of these mirrors are then determined. A movable model is made to illustrate the law of sines; and the index of refraction of water is determined as follows:—

"Graduate slip of glass about 8 C.M. \times 1 C.M. to M.M. Fix with sealing-wax two equal slips about 4 C.M. long at right angles to scale thus . Place in water so that uprights are just below surface. Fix an eye-tube (blackened inside) at some distance above water and in line of scale, and note division at which top of nearest upright appears on scale. Now carefully withdraw water without disturbing apparatus, and again note division. Let height of upright be H , and distances on scale from upright respectively a and A , then $\frac{A}{H} =$ tangent of angle of incidence, and $\frac{a}{H} =$ tangent of angle of refraction.

From tangent calculate sines, using formula $\sin \theta = \frac{\tan \theta}{\sqrt{1 + \tan^2 \theta}}$. Index of refraction $\approx \frac{\text{Sine of angle of incidence.}}{\text{Sine of angle of refraction.}}$

Verify result by varying angles."

A bisulphide of carbon lens is made from two watch glasses with ground edges, a notch being cut across to introduce the liquid. A bisulphide of carbon prism is not so easy to make; here is the method recommended:—

"Cut-off and grind ends of glass tube about 2 inches long \times $\frac{3}{4}$ inch diameter so that planes of ends make an angle of about 60° with each other. Drill hole about $\frac{1}{8}$ inch diameter in middle of tube with hardened point of triangular file and turpentine. Glue pieces of thin sheet glass on ends. Fill with Bisulphide of Carbon and cover hole with glued paper."

By degrees a spectroscope is entirely built up, and with

it the spectra of various metallic vapours are examined till some familiarity is acquired with different spectra. Finally, a polariscope is made and different objects for examination are devised. Our space is more than exhausted, and we cannot follow the teachers further in their work. Time will, no doubt, bring greater experience and improve an already admirable course.

As we remarked in a former article, the good work done by the Department must sooner or later indirectly affect all classes. We trust the time is not far distant when the pressure of public opinion will lead men and women alike to feel but half educated if they have no acquaintance with the living facts and solid ground of nature. The happy results of such a change will soon become apparent. Already, indeed, society is becoming more interested in science. Some knowledge of the methods and results of scientific inquiry is penetrating the population. New habits of thought and modes of reasoning are spreading widely. A juster estimate of the position of the scientific explorer is being held. At the same time a truer knowledge of nature is diffusing more profound and doubtless more reverent conceptions of the orderly mystery that surrounds us.

CARUS AND GERSTAECKER'S "HANDBUCH
DER ZOOLOGIE"

Handbuch der Zoologie. Von Jul. Victor Carus und C. E. A. Gerstaecker. (Leipzig: Engelmann.)

THE second volume of this work appeared in 1863, the first part of the first volume in 1868, and at length the book is completed by the appearance of the second part of the first volume in 1875. It is somewhat late in the day to review the earlier parts of the undertaking, but looking at it as a whole, we do not hesitate to say that the "Handbuch" in which Prof. Carus has had the chief share (the Arthropods alone are treated by Prof. Gerstaecker) is eminently useful and worthy of his high reputation for perspicacity and practical good sense. There are few men to whom zoologists both in this country as well as in his fatherland, are so much indebted for solid help in their labours of research or of instruction as to Prof. Victor Carus. Who has not felt grateful to him for the "Bibliotheca Zoologica," which bears his name? What naturalist of this generation has not consulted, as a storehouse of inexhaustible treasure, the "Icones Zootomicæ," which, after twenty years, continues to hold its place as the most valuable pictorial treatise on the Invertebrata which we possess? Prof. Carus has further served his countrymen by acting as the competent translator of Mr. Darwin's works—and to us he has lent timely aid by discharging for two years the duties of the Edinburgh chair of Natural History in the absence of Prof. Wyville Thomson. In an enumeration of the labours of this kind for which zoologists have to thank Prof. Carus, we must not omit the volume on the history of Zoology—published in the Munich series of histories of the sciences—a work which is full of the most interesting details of the early beginnings and strange developments of the study of animal form.

It will not be out of place, whilst strongly recommending this book to the reader as a most trustworthy, succinct, and withal ample exposition of the facts of animal morpho-

logy in especial relation to the "system" or classification of the Animal Kingdom—to say a few words as to its method and order of treatment. The first volume (that most recently published) contains the Vertebrata, the Mollusca, and Molluscoidea. The second volume treats of the Arthropoda, Echinodermata, Vermes, Cœlenterata, and Protozoa. The groups of the animal kingdom are thus discussed in a descending order, beginning with the highest: at the same time each section treating of a sub-kingdom is complete in itself. The section of the work treating of any one sub-kingdom starts with a brief definition of the group of some ten or fifteen lines in length. Then follow several pages treating of the characteristic disposition of the various organs and their variation in the following order, (1) general form, (2) integument, (3) muscular system, (4) skeleton, (5) nervous system, (6) organs of sense, (7) digestive canal, (8) respiratory organs, (9) vascular system, (10) urinary and generative organs, (11) development, metamorphoses and reproduction of parts, (12) geographical and geological distribution, (13) chief systems of classification hitherto proposed, with an outline of the classification adopted by the author, brief definitions (about ten lines each) of the classes being introduced. After this we have the detailed consideration of each class, the highest being taken first. The same method is adopted in the exposition of the characters of the class as in the treatment of the sub-kingdom—as much as twenty-four pages being thus devoted to the class Mammalia. To the class follows an enumeration of its orders, each order being *briefly* characterised in the list and then taken in turn, the highest first, for more detailed treatment. Some additional facts with regard to each order beyond those introduced in the brief definition are given when it is thus taken in its turn, and under it are placed in succession with their characteristics briefly stated, the families and sub-families and genera, the enumeration of the latter being *complete*. The principal genera are characterised—referred to their authors whilst synonyms and sub-genera are indicated. The work goes so far into detail as to cite under the genera many of the commoner or more remarkable species—with a statement of the geographical and geological distribution of the genus. After the description of an order or other large group, we usually find a bibliographical list referring the reader to the more important monographs relating to the particular group. Thus the "Handbuch" furnishes us—within the limits which are possible in an ever-growing science—with a treatise on comparative anatomy, combined with an exhaustive enumeration of the genera hitherto distinguished by zoologists, referred to a definite place in a scheme of classification. As the latest complete systematic treatise on the Animal Kingdom, and one executed with the exercise of most conscientious care, and a very exceptional knowledge of the vast variety of zoological publications which now almost daily issue from the press—this work is one which is sure to render eminent service to all zoologists. We can speak to the usefulness of the earlier volume, from an experience of some years, and there is every reason to believe that the one just completed will be found as efficient.

Having said thus much in favour of the "Handbuch," we shall proceed to point out some of its shortcomings, which